New Pneumatic Artificial Muscle
Realizing Giacometti Robotics and Soft Robotics

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Abstract: Two concepts of new robotics—Giacometti robotics and soft robotics—are proposed in this paper towards robotics at the next stage. A key element realizing them is a new pneumatic artificial muscle. This paper presents a thin pneumatic artificial muscle developed by the author and its applications to Giacometti robots and soft robots, which are still at the very early development stage but have a considerable potential in new robotics.

Keywords: Pneumatic rubber actuator, Artificial muscle, Giacometti robotics, Soft robotics

1. Towards robotics at the next stage

I think that robotics is now at a turning point. Over the past several decades, robotics has greatly advanced and has currently shifted towards a more practical stage. I think that basic robotics based on linkage mechanisms has become almost complete and that academia should aim for new robotics.

Two concepts of new robotics are presented in this paper—Giacometti robotics and soft robotics. Their design policies are quite different from those of conventional robotics.

A key element to realize these two new concepts is a new pneumatic artificial muscle.

2. Thin McKibben muscle

McKibben muscle was originally developed in the USA at the end of 1950s [1]. It consists of a rubber tube with braided cords around it. The application of pneumatic pressure in the rubber tube causes expansion of the tube in the radial direction, which changes the crossing angle between the cords. This results in the muscle contracting in the axial direction, making it work similar to actual human muscles.

We have succeeded in the mass production of several thin McKibben muscles, which are 0.6 mm to 10 mm in diameter [2]. Examples are shown in Fig. 1. The muscle with a diameter of 1.8 mm in Fig. 1 causes a maximum contracting ratio of 25% and a maximum contracting force of 6 N. The weight is only 1 g/m.

Bundling them realizes various muscles such as biceps and splenius muscles, which are often found in animal bodies. An interesting point is that bundled muscles exhibit a larger contracting ratio than that of a single muscle [2]. This originates from the physical interaction between muscles.

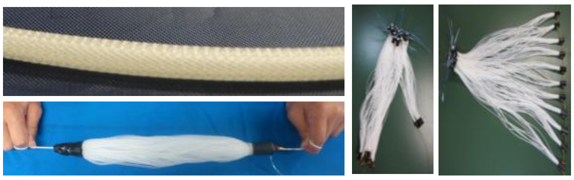

Fig. 1 Thin muscle with a diameter of 1.8 mm (upper left), bundled muscles (50 muscles, lower left), and muscles with various shapes (right)

3. Giacometti robotics

Robot researchers/designers have been seeking robots with higher performance and with more equipment since the beginning of robotics. Although this results in many highly functional robots with high specification, they have heavy bodies and complicated control systems. This causes another technical problem related to safety for practical uses.

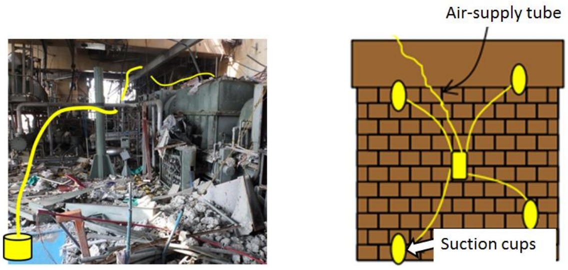

Fig. 2 Examples of Giacometti robots. A 20-m-long cantilever robot arm for inspection (left) and lightweight wall-climbing robot (right)

For example, if a robot falls down stairs or becomes stuck in rubble, the damage to the robot and the circumstances would be very large.

Giacometti robotics has the potential to solve these problems in a way that is very different from conventional robots. “Giacometti robotics” was named by myself after Alberto Giacometti, a Swiss sculptor. Giacometti robots consist of very thin, very light, and very long arms and legs, which are similar to his sculptures. His artistic style of essential design by removing fat also matches this new robot concept.

Examples are shown in Fig. 2. A thin, light, and long cantilever arm equipped with a small camera at the tip will easily make inspection in disaster areas possible without walking in rubble with a heavy body. Our analysis shows our thin muscles can realize a 20-m-long thin cantilever robot arm, which has been difficult with conventional actuators. A wall-climbing robot with a very light body can also be realized, which may be safe enough, even if it falls down.

4. Power-support wear

Knitting muscles will realize soft and comfortable power-support wear for physically disabled persons or for heavy-lifting workers.

A conceptual image is shown in Fig. 3 (left), which is still at the beginning stage of development. A prototype of active cloth knitted with thin muscles is shown in Fig. 3 (right), which is very flexible and works well with a contracting ratio of 20%.

The first trial applying this research is now being planned for heavy-lifting work in the backyard of the Haneda airport, where many workers handle many large baggage with a weight of 20–30 kg.

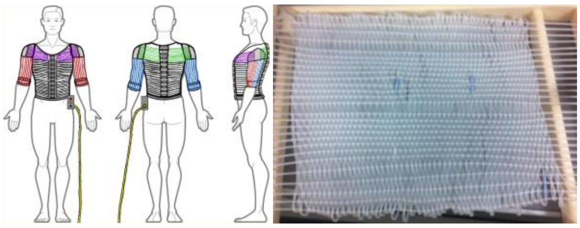

Fig. 3 Image of a power-support suit made from thin muscles (left) and active cloth made from muscles (right)

5. Redundant musculoskeletal robot mechanism

There are still many large differences between the driving mechanisms of robots and human bodies [3]. Examples are 1) the redundancy of muscles for motion; the numbers of actuators and DOFs are quite different, 2) the joint structure (fixed axis for robots and shifting and distributed joint axes for humans), and 3) the backdrivability.

We are carrying out research on musculoskeletal robot mechanisms that mimic human mechanisms with muscles and joints. The robot exhibits very similar kinematic and static characteristics as human bodies.

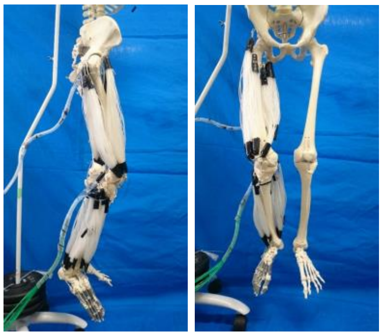

Fig. 4 A musculoskeletal robot mechanism with a very redundant drive mechanism having 50 independent muscles

6. Conclusion

Two concepts of new robotics and the key elements for realizing them are discussed. Although they are still in the very early stage of development, we are carrying out research for new robotics for several big research programs in Japan.

A thin pneumatic muscle is also presented, which has a much higher ratio of force/weight and a great potential to realize the two new robotics concepts.

A major problem of pneumatic actuators in general is that they are wired actuators; driving them requires a compressor and air-supply tubes, which make them impossible to work in mobile equipment. In my talk, I will discuss our new R&D activity [4] to solve this problem and other soft robotics [5].

References

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